PRELIMINARY COPY

INSTRUCTION MANUAL

MODEL 502A

MILLIOHMMETER

KEITHLEY INSTRUMENTS

INSTRUCTION MANUAL

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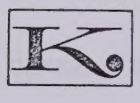

KEITHLEY INSTRUMENTS. INC.

The attached Instruction Manual for the Model 502A is a preliminary edition.

The information contained in it is complete and accurate.

Within a month we will send you a finished printed manual complete with component photographs, if you will return the blue warranty card attached to the front cover.

502 A

KEITHLEY INSTRUMENTS, INC.

12415 EUCLID AVENUE • CLEVELAND, OHIO 44106 • (AREA CODE 216) 795-2666

SECTION 1. GENERAL DESCRIPTION.

1-1. GENERAL.

a. The Keithley Model 502A is a battery-operated milliohmmeter with 13 ranges from 0.001 ohm full scale to 1000 ohms. Minimum detectable resistance is 30 micro-ohms. Accuracy is ±3% of full scale on all ranges except the 0.001-ohm range, where it is ±5% of full scale.

b. The Milliohmmeter uses a 4-terminal ammeter-voltmeter technique to measure resistance. Two terminals furnish a 100-cps square wave test current to the sample. Two other terminals measure the resulting voltage drop across the sample. The voltage is measured by a relatively high-impedance rectifier-type voltmeter.

c. This circuit eliminates zero drift and minimizes errors caused by thermal emf's Also, the Model 502A can measure a sample which has a biasing dc current superimposed upon it without affecting its accuracy.

1-2. FEATURES.

a. The Model 502A has a voltage limited mode, in which the open circuit voltage across the sample will not exceed 25 millivolts. This is intended especially for use in dry-circuit measurements. For example, this mode prevents the voltage breakdown of oxide films on contacts which would then cause a false measurement.

b. Maximum power dissipation in a sample with improper range setting is 3 mill8-watts. Maximum dissipation caused by instrument component failure and improper range setting is 6 milliwatts.

c. The reading is presented on a linear scale panel meter. No calibration adjustments are required during the measurement.

d. An OPERATE-ZERO Switch short-circuits the input to the voltage amplifier. This speeds testing by preventing the meter from going off scale while connecting the leads to the sample.

1-3. APPLICATIONS. The Model 502A is a sturdy, portable Milliohmmeter designed for fast, accurate, low-resistance measurements in the laboratory and the field. Typical uses include measuring resistivity of semi-conductors and liquids, corrosion tests, testing of switch and relay contacts, printed circuits, fuses, grounding systems and wave-guides. The very low power dissipation in a sample makes the Model 502A especially suitable for safe checking of squibs, carbon bridges and similar explosive devises. Other applications are measuring resistivity profiles in thermoelectric materials, making temperature measurements using thermistors and measuring electrolytic conductivity. The Milliohmmeter can also measure resistance variations in a sample through which dc current flows.

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1-4. SPECIFICATIONS

RANGE, ohms	Average Applied Full-Scale Current, milliamperes	Average Full-Scale Voltage Drop, microvolts	Maximum Dissipation in Sample, microwatts
0.001	10	10	0.2
0.003	10	30	0.6
0.01	10.00	100	2.00
0.03	3.33	100	0.66
0.1	1.00	100	0.2
0.3	0.33	100	0.066
1.0	0.1	100	0.02
3.0	0.2	600	0.24
10	0.06	600	0.072
30	0.02	600	0.024
100	0.006	600	0.0072
300	0.002	600	0.0024
1000	0.0006	600	0.00072

NORMAL MODE:

Accuracy: ±3% of full scale from 1000-ohm to 0.003-ohm ranges; ±5% of full scale on 0.001-ohm range. Less than 2% error is added in measuring samples with a series reactance of 4% of sample resistance.

Safety: Maximum voltage across sample, 1.4 volts. Maximum power dissipation due to improper range setting, 3 milliwatts. Maximum power dissipation due to component failure and improper range setting, 6 milliwatts.

VOLTAGE LIMITED MODE:

Accuracy: Degraded from Normal Mode by 2% to 10%; after an on-scale reading is obtained, the unit may be safely switched to the normal mode for a more accurate reading.

Safety: Maximum voltage applied across sample, 25 millivolts peak-to-peak. Maximum power dissipation due to improper range setting, 65 microwatts.

ZERO DRIFT: None.

WARM-UP TIME: 30 seconds.

INPUT ZERO: Lever switch prevents off-scale meter indications while changing samples.

RISE TIME: (10% to 90%): 1 second on all ranges.

REPEATABILITY: Within 2%.

CONNECTORS: Test Leads: Amphenol 80-PC2F.

BATTERY COMPLEMENT: Four E146 (8.4 v); two RM401R (1.34 v), two RM42R (1.34 v); 360 hours minimum life.

ACCESSORIES SUPPLIED: Model 5022 Current and Voltage Leads; one set alligator clips; one set Miniprod adapters; mating connectors.

DIMENSIONS, WEIGHT: 9 inches high x 6 inches wide x 7 inches deep; net weight, 7-1/2 pounds.

1-5. EQUIPMENT SHIPPED. The Model 502A Milliohmmeter is factory-calibrated and is shipped with all components in place. The shipping carton also contains the Instruction Manual. Inside the Model 502A carrying case, there are a pair of Model 5022 Current and Voltage Leads, one set of alligator clips, one set of Miniprod adapter tips and mating plugs.

SECTION 2. OPERATION

2-1. FRONT PANEL CONTROLS AND TERMINALS

a. Power Switch. The Power Switch has three positions: In OFF, the Model 502A power supply is disconnected. In VOLTAGE LIMITED, the maximum open-circuit voltage across the sample is never more than 25 millivolts. This mode is used where the magnitude of the sample's resistance is not known. In the NORMAL position, the Model 502A operates as a milliohmmeter with its best performance specifications.

b. OPERATE-ZERO Switch. The OPERATE-ZERO Switch is a 2-position toggle switch. When the Switch is in the OPERATE position, the Milliohmmeter will measure. Putting the Switch in ZERO position shorts the voltage input and allows connecting a sample without overloading the instrument.

c. Range Switch. The Range Switch has 13 overlapping range positions from .001 ohm full scale to 100 ohms. A CAL position enable the instrument to be checked for a meter deflection of 7.

d. CALIBRATE Control. The CALIBRATE Control is a potentiometer immediately beneath the Range Switch. It adjusts the meter deflection to 7 when the Range Switch is set to CAL.

e. CURRENT and VOLTAGE Receptacles. Two microphone-type receptacles are used for the Model 5022 Test Leads. Either lead may be used in either receptacle. A diagram shows the lead hookups for measuring a sample.

2-2. INPUT CONNECTIONS.

a. Measuring samples of less than 3 ohms.

1. Connect the Model 5022 Test Leads to the VOLTAGE and CURRENT Receptacles. Connect the alligator clips with like color insulators to the same sides of the resistance sample. Refer to Figure 3.

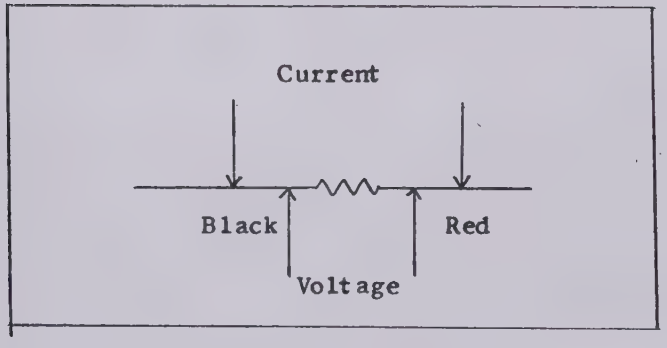

Figure 3.

2. Connect the current leads to any point around the sample or to any point within the sample. Make sure, however, current flows through the entire portion of the sample which will be measured. Connect the voltage leads across only that part of the sample which will be measured. The Model 502A measures the resistance between the two points to which the voltage leads are connected.

NOTE

Do not connect the voltage leads to the current leads when measuring samples with resistances less than 3 ohms. If this is done, the clip resistance and the clip-to-sample contact resistance will be included in the measurement. This will naturally increase the reading.

b. Measuring samples of 3 ohms and more. The clip-contact resistance is not significant when using the 3-ohm and greater ranges. The two pair of leads may be paired together and the two-terminal ohmmeter methods used. The four-terminal methods, given above, may also be used, but the two-terminal method is faster for repeated testing.

2-3. OPERATING PROCEDURES.

a. Turn the Power Switch to the VOLTAGE LIMITED position. Set the OPERATE-ZERO Switch to ZERO. Wait 15 seconds for the Milliohmmeter to warm up.

b. Connect the leads to the sample as described in paragraph 2-2.

c. Set the OPERATE-ZERO Switch to OPERATE. Set the Range Switch to the proper range. Turn the Power Switch to NORMAL. Take the readings directly from the meter.

d. Set the OPERATE-ZERO Switch to ZERO when connecting the leads to the sample. When the switch is in ZERO, the voltage input is shorted, and the Milliohmmeter can not be overloaded. An accidental overload will not damage the Model 502A. However, it will take approximately 30 seconds for the amplifier to recover.

e. It is convenient to check the Model 502A calibration. Set the Range Switch to CAL and the OPERATE-ZERO Switch to OPERATE. The Milliohmmeter should read withing 1 minor division of 7. If necessary, adjust the CALIBRATE Control on the front panel to a meter deflection of 7. If the control will not make the adjustment, check the batteries within the instrument.

2-4. 60-CPS PICK-UP.

a. On the 1-ohm and lower ranges, the Model 502A is sensitive in the microvolt region and has a pass band which includes 60 cps. A loop in the voltage lead which encloses a 60-cps magnetic field may cause a meter deflection. Avoid such loops. Also be careful to avoid electrostatic pick-up, although it is not serious at the impedances involved.

b. To test for pick-up, remove the current leads when the voltage leads are connected to the sample. If no reading appears, there is no pick-up. If a reading appears, reduce the pick-up by rotating the instrument for minimum deflection. Even if pick-up is present, however, the Milliohmmeter will still read within specifications above any residual reading For example, if the Model 502A reads 0.002 ohm due to stray fields with the voltage leads shorted, a 0.003-ohm resistance being tested will still read 0.003 ohm. This is because the dc level of the rectified signal will be greater than the peak-to-peak value of the 60-cps signal. In this case, the 60-cps signal will be superimposed on the test signal and it will not be rectified.

2-5. INDUCTANCE AND CAPACITANCE.

a. The Model 502A measures resistance using 40-cps current through the sample. Using the ac current means inductive and capacitive components in the sample or in the input cir-

cuit will cause some wave form distortion and erroneous readings. The amount of error normally encountered in a measurement is small and within the Model 502A specifications. For instance, series inductive impedance at 94 cps or less than 4% of the resistance of the sample causes the reading to be less than 2% low. Table gives the maximum capacitance and inductance value which will cause an inaccuracy of 2% of full scale on any range.

Range, ohms	Maximum Series Inductance, millihenries	Maximum Shunt Capacitance, microfarads
0.001	.00006	more than 1000
0.003	.0002	more than 1000
0.01	.0006	more than 1000
0.03	.002	more than 1000
0.1	.006	700
0.3	.02	225
1.0	.06	70
3.0	.2	22.5
10	.6	7
30	2	2.25
100	6	.7
300	20	.225
1000	60	.07

Table 1. Maximum Capacitance and Inductance Allowed by Range. Capacitances and inductances in the sample or input circuit below the above amount for any one range will introduce less than 2% in the Model 502A reading. This is within the Milliohmmeter's accuracy specification.

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL.

a. The Keithley Model 502A Milliohmmeter consists of a 94-cps constant current source combined with an ultra-sensitive ac vacuum tube voltmeter. Using ac techniques eliminates zero drift, and large negative feedback maintains factory calibration. Since both the current source impedance and the VTVM input impedance are high, connector and lead resistances are insignificant.

b. The current source consists of a pair of transistors connected as a multivibrator. An output transistor operates as a switch and places the full battery voltage in series with the resistor which determines the test current for each range.

c. The voltmeter consists of an input transformer with a 60:1 step up ratio, a 5-stage subminiature tube amplifier, and an indication meter in an overall feedback loop.

3-2. CURRENT SOURCE

a. A multivibrator, made of transistors Q101 and Q202, generates the 94-cps square wave current. Potentiometer R159 set at the factory, adjusts the symmetry of the square wave. Transistors Q103 and Q104 are power amplifiers for the ac current. Transistor Q104 acts as a 94-cps switch, connecting and disconnecting battery BT107 across the sample and the series resistors, R134 and R154, selected with the range switch. Because the output peak voltage is more than 95% of the mercury battery voltage, changes of the transistor parameters cause very small changes in the square wave amplitude.

b. Battery BT108 supplies a negative bias current through resistor R162 to the output transistor, Q104, to insure good cut-off characteristics at high ambient temperature.

c. When the Power Switch is in VOLTAGE LIMITED position, internal resistors R133 and R135 through R144 are shunted across the sample. The value of these resistors are chosen so that the maximum voltage drop due to current from the multivibrator is limited to 25 millivolts, even with an improper setting of the Range Switch.

3-3. AC AMPLIFIER.

a. The ac amplifier is a conventional vacuum tube voltmeter with meter current feedback. The input signal is matched to the vacuum tube input by an input transformer, T101, on the more sensitive ranges. Above the 1-ohm ranges, the transformer is not used.

b. The input voltage is compared to the feedback voltage through resistors R101 and R102 into the grid of tube V101. Tubes V101 through V105 amplify the error signal. The output voltage is full-wave rectified by diodes D101 and D102 to supply indicating meter current. The current flows through resistors R130 to R132 to supply feedback voltage to the first stage.

c. Potentiometer R125 is used to calibrate the ranges which do not use transformer input; potentiometer R129 is used for calibrating the ranges which do use the transformer input.

d. When the Range Switch is set on CAL, the Model 502A is placed in its 1000-ohm range. A 700-ohm, 1% resistor, R163, is connected into the test position and the external voltage and current leads are disconnected. The CALIBRATE potentiometer, R , then can be used to adjust for a reading of 7. Since the current drain is essentially the same on all ranges, a reading less than normal usually indicates faulty batteries.

SECTION 6. REPLACEABLE PARTS

6-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Model 502A and its accessories. The List gives the circuit designation, the part description, a suggested manufacturer, the manufacturer's part number and the Keithley Part Number. The name and address of the manufacturers listed in the "Mfg. Code" column are contained in Table 5.

6-2. HOW TO ORDER PARTS.

a. For parts orders, include the instrument's model and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those parts coded for Keithley manufacture (80164) must be ordered from Keithley Instruments, Inc. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

b. Order parts through your nearest Keithley distributor or the Sales Service Department, Keithley Instruments, Inc.

amp	ampere	Mil. No.	Military Type Number
		My	Mylar
Comp	Composition		
		Ω	ohm
DCb	Deposited Carbon		
		PM	Paper, metallized
ETB	Electrolytic, tubular	Poly	Polystyrene
		p	pico (10^{-12})
f	farad		
		μ	micro (10^{-6})
k	kilo (10^{3})		
		v	volt
M or meg	mega (10^{6}) or megohms	Var	Variable
m	milli (10^{-3})		
Mfg.	Manufacturer	w	watt
MtF	Metal Film	WW	Wirewound
		WWVar	Wirewound Variable

Abbreviations and Symbols.

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D101	Silicon	1N645	01295	RF-14	
D102	Silicon	1N645	01295	RF-14	

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
M101	Meter	80164	ME-59	
S101	Toggle Switch, OPERATE-ZERO (Mfg. No. 3003-DL)	82389	SW-59	
S102		80164	SW-195	
S103		80164	SW-196	
T101	Transformer	80164	TR-53	

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	1 MΩ	1%, 1/2 w	MtF	07716	MECT-8	R53-1M	
R102	1 MΩ	1%, 1/2 w	MtF	07716	MECT-8	R53-1M	
R103	2.2 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-2.2M	
R104	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R105	22 MΩ	10%, 1/2 w	Comp	01121	EB	R1-22M	
R106	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R107	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	
R108	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	
R109	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R110	47 kΩ	10%, 1/2 w	Comp	01121	EB	R1-47K	
R111	22 MΩ	10%, 1/2 w	Comp	01121	EB	R1-22M	
R112	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R113	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R114	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	
R115	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R116	22 MΩ	10%, 1/2 w	Comp	01121	EB	R1-22M	
R117	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R118	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	
R119	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	
R120	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R121	47 kΩ	10%, 1/2 w	Comp	01121	EB	R1-47K	
R122	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R123	47 kΩ	10%, 1/2 w	Comp	01121	EB	R1-47K	
R124	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	
R125	20 kΩ					RP34-20K	
R126	65 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-65K	
R127	5 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-5K	
R128	5 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-5K	
R129	1 kΩ	10%, 5 w	WWVar	71450	AW	RP3-1K	
R130	91 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-91	
R131	300 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-300	
R132	1 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1K	
R133	1 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-1	
R134	60 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-60	
R135	3.33 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-3.33	
R136	10 Ω	10%, 1/2 w	Comp	01121	EB	R1-10	
R137	33 Ω	10%, 1/2 w	Comp	01121	EB	R1-33	
R138	100 Ω	10%, 1/2 w	Comp	01121	EB	R1-100	
R139	56 Ω	10%, 1/2 w	Comp	01121	EB	R1-56	
R140	180 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-180	
R141	560 Ω	10%, 1/2 w	Comp	01121	EB	R1-560	
R142	1.8 kΩ	10%, 1/2 w	Comp	01121	EB	R1-1.8K	
R143	5.6 kΩ	10%, 1/2 w	Comp	01121	EB	R1-5.6K	
R144	18 kΩ	10%, 1/2 w	Comp	01121	EB	R1-18K	
R145	180 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-180	
R146	600 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-600	
R147	1.8 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1.8K	
R148	6 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-6K	
R149	3 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-3K	
R150	10 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-10K	
R151	30 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-30K	
R152	100 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-100K	
R153	300 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-300K	

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D101	Silicon	1N645	01295	RF-14	
D102	Silicon	1N645	01295	RF-14	

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S101	Toggle Switch, OPERATE-ZERO (Mfg. No. 3003-DL)	82389	SW-59	
S102		80164	SW-195	
S103		80164	SW-196	
T101	Transformer	80164	TR-53	

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Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	1 MΩ	1%, 1/2 w	MtF	07716	MECT-8	R53-1M	
R102	1 MΩ	1%, 1/2 w	MtF	07716	MECT-8	R53-1M	
R103	2.2 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-2.2M	
R104	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R105	22 MΩ	10%, 1/2 w	Comp	01121	EB	R1-22M	
R106	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R107	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	
R108	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	
R109	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	
R110	47 kΩ	10%, 1/2 w	Comp	01121	EB	R1-47K	
R111	22 MΩ	10%, 1/2 w	Comp	01121	EB	R1-22M	
R112	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K	
R113	2.2 MΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2M	

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R154	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M	
R155	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M	
R156	82 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-82	
R157	3 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-3K	
R158	7 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-7K	
R159	10 kΩ	10%, 2 w	WWVar	71450	WP	RP9-10K	
R160	7 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-7K	
R161	3 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-3K	
R162	15 kΩ	10%, 1/2 w	Comp	01121	EB	R1-15K	
R163	700 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-700	
R164	1.8 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1.8K	
R165	333 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-333	

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q101	2N1381	01295	TG-18	
Q102	2N1381	01295	TG-18	
Q103	2N1381	01295	TG-18	
Q104	2N1381	01295	TG-18	

VACUUM TUBES

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
V101	6419	81453	EV-CK6419	
V102	6419	81453	EV-CK6419	
V103	6419	81453	EV-CK6419	
V104	6419	81453	EV-CK6419	
V105	6418	80164	EV-CK6418	

FURNISHED ACCESSORIES

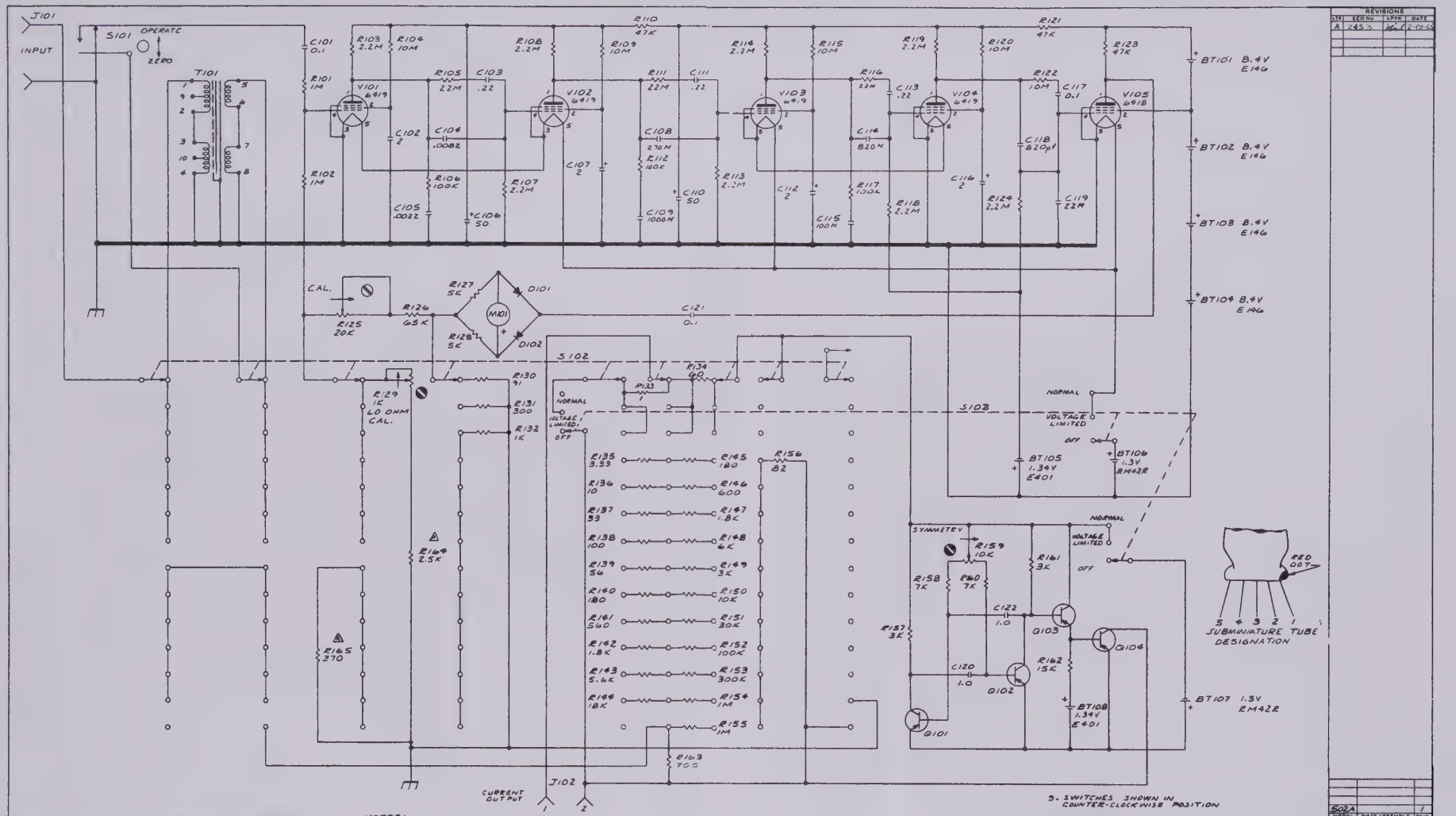
Description	Mfg. Code	Mfg. Part No.	Keithley Part No.
Two Alligator Clips, red	83330	304	AC-3R
Two Alligator Clips, black	83330	304	AC-3B
Two Miniprod Adapter Tips, red	08811	33-160	PP-3R
Two Miniprod Adapter Tips, black	08811	33-162	PP-3B

FURNISHED ACCESSORIES (Cont'd)

Description	Mfg. Code	Mfg. Part No.	Keithley Part No.
Current and Voltage Lead Assemblies	80164		18480C
. Plug, Microphone	02660	80MC2M	CS-33
. Phone Tip, Red	83330	237	PP-2R
. Phone Tip, Black	83330	237	PP-2B

00656	Aerovox Corp. New Bedford, Mass.
00686	Film Capacitors, Inc. New York, N. Y.
01121	Allen-Bradley Corp. Milwaukee, Wis.
01295	Texas Instruments, Inc. Semi-Conductor-Components Division Dallas, Texas
02660	Amphenol-Borg Electronics Corp. Broadview, Chicago, Illinois
04009	Arrow-Hart and Hegeman Electric Co. Hartford, Conn.
07716	International Resistance Co. Burlington, Iowa
08811	G-C Electronics Co., Inc. Camden, N. J.
10608	Union Carbide Corp. New York, N. Y.
37942	Mallory, P. R., and Co., Inc. Indianapolis, Ind.
71450	CTS Corp. Elkhart, Ind.
75042	International Resistance Co. Philadelphia, Pa.
79727	Continental-Wirt Electronics Corp. Philadelphia, Pa.
80164	Keithley Instruments, Inc. Cleveland, Ohio
81453	Raytheon Co. Industrial Components Div. Industrial Tube Operation Newton, Mass.
82389	Switchcraft, Inc. Chicago, Ill.
83330	Smith, Herman H., Inc. Brooklyn, N. Y.
84171	Arco Electronics, Inc. Great Neck, N. Y.
84411	Good-All Electric Mfg. Co. Ogallala, Nebr.

Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)



REVISIONS			
LTR	ECO No	APPR	DATE
A	2455	MM	2-10-65

REFERENCE DESIGNATIONS NOT USED				HIGHEST REFERENCE DESIGNATIONS			
				C165	T101	M101	C122
				1105	Q104	S103	J102
				BT108	D102		

NOTES:
1. pf - PICOFARADS
2. ↑ - CLOCK WISE ROTATION
3. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS RESPECTIVELY UNLESS OTHERWISE NOTED.
4. ⊘ INTERNAL SCREWDRIVER ADJ.
5. ○ INDICATES FRONT PANEL CONTROL
6. ⊘ INDICATES FRONT PANEL SCREWDRIVER ADJ.
7. M - MEGOHM
8. K - 1000 OHM
9. SWITCHES SHOWN IN COUNTER-CLOCKWISE POSITION

DRN	D.D.L.	DATE 11-23-66
CHD	RLE	DATE 12-27-67
ENG APPR	WFM	DATE 12-29-67
PILOT RELEASE		DATE
PROD RELEASE		DATE

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

MATERIAL

FINISH

TITLE: SCHEMATIC

PART NUMBER: 18346E

502A		
MODEL	NEXT ASSEMBLY USED ON	QUAN

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof (except tubes and batteries) which, within a year after shipment, proves defective upon examination.

To exercise this warranty, contact your Keithley field engineering representative. You will be given assistance and shipping instructions.

REPAIRS AND RECALIBRATION

Keithley Instruments and its international distributors maintain complete repair facilities.

To insure prompt repair or recalibration service, please contact your Keithley field representative before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

KEITHLEY INSTRUMENTS, INC.
12415 EUCLID AVENUE
CLEVELAND, OHIO 44106